

# **Solid Oxide Fuel Cells: Challenges and Opportunities**

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**Acumentrics**  
**CORPORATION**

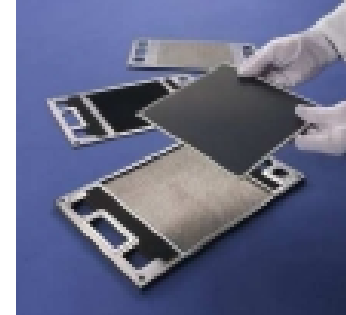
# Primary Advantages of the SOFC

- Long life – over 25,000 hours
- CO Tolerance – a fuel not a poison
- Internal reformation of light hydrocarbons
- Inexpensive cell materials – no special catalysts
- High-grade waste heat – 400-600 °C

# Major Concerns with the SOFC

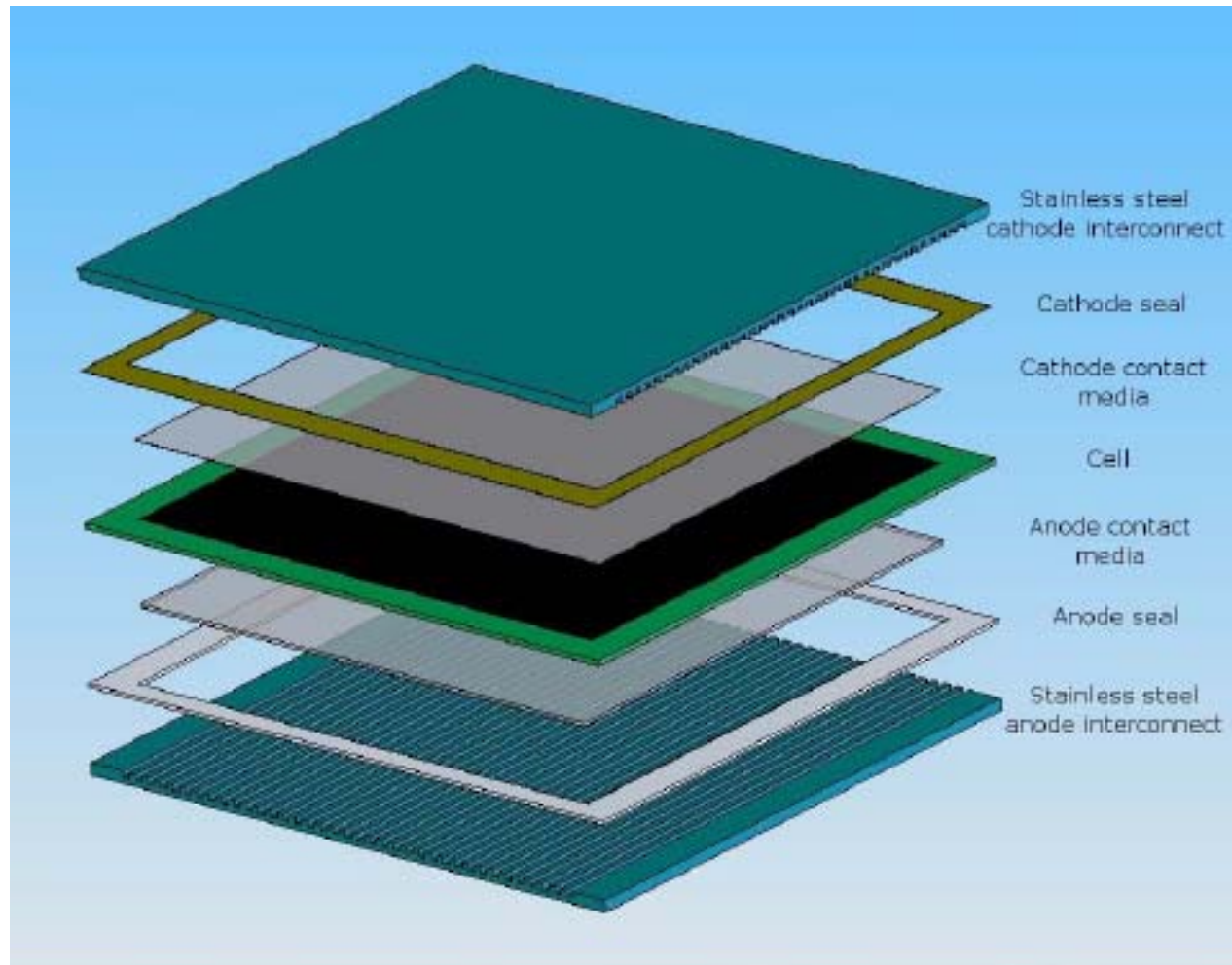
- Short life of peripheral seals – need for perfectly flat plates, use of brittle seals
- Poor yield – lack of uniformity of coatings, problems in firing, mismatch of coefficients of thermal expansion of three layers
- Mechanical stress on temperature change leading to long start-stop cycle
- Low power and volumetric density (bulky)
- Coking if fuel-air ratio off

# Advantages of Tubular SOFC



	<b>Acumentrics</b>	<b>Planar</b>
<b>Start-up Time</b>	< 45 minutes	Hours
<b>Thermal Cycles</b>	>100 proven	<10 preferred
<b>Pressurized fuel</b>	Not needed	Yes
<b>Reforming</b>	Internal	External
<b>Sealing</b>	Metallic, small area, deformations OK	Brittle glass at periphery, need for perfect flatness
<b>Interconnect</b>	Silver Wire	Coated Metal Alloy
<b>Supports</b>	Nickel Tube	High Alloy Metal
<b>Power Density</b>	330 mW/cm <sup>2</sup>	420 mW/cm <sup>2</sup>

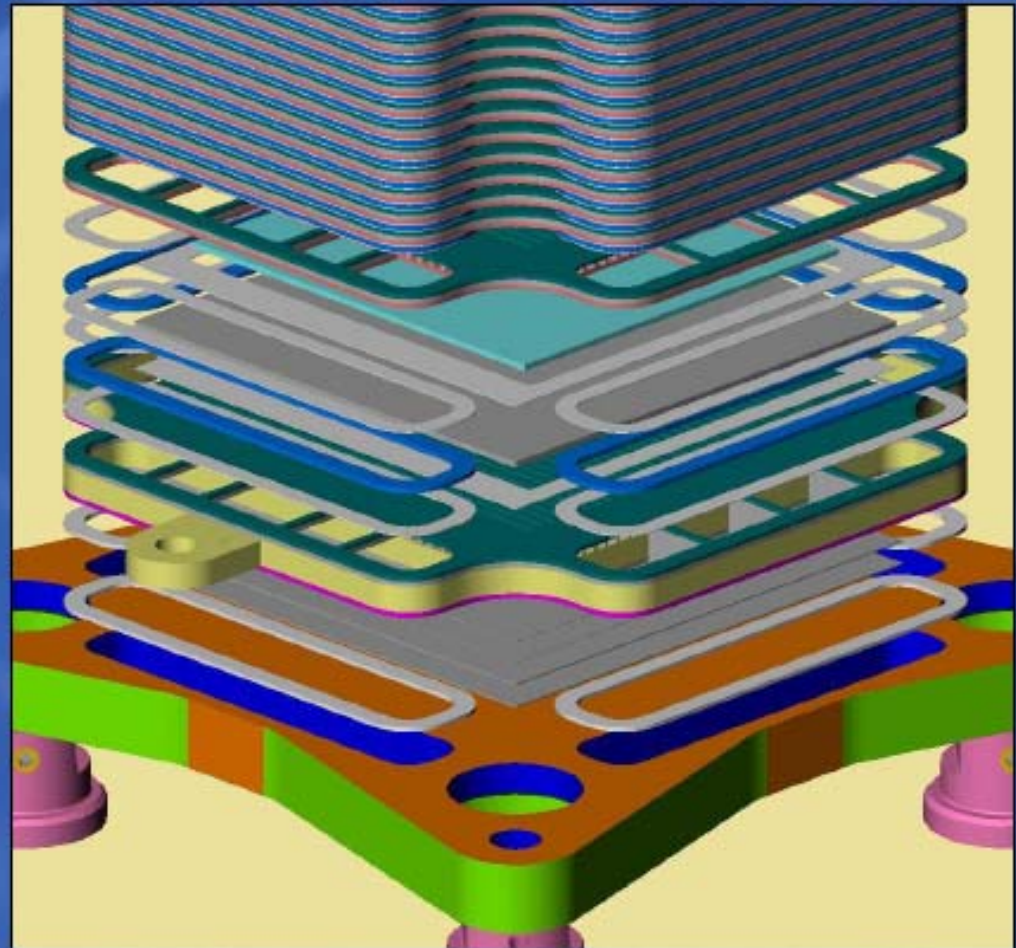
# Typical Planar Structure (Versa Power)





## Baseline Stack

- Anode supported cells ~1mm in thickness
- Uncoated ferritic stainless steel sheet metal interconnect
- Cross-flow fluid delivery with manifolds integrated into the interconnect but not through the cell
- Compressible ceramic gasket seals
- External compression system



# Actual Assembled Stack (Versa)





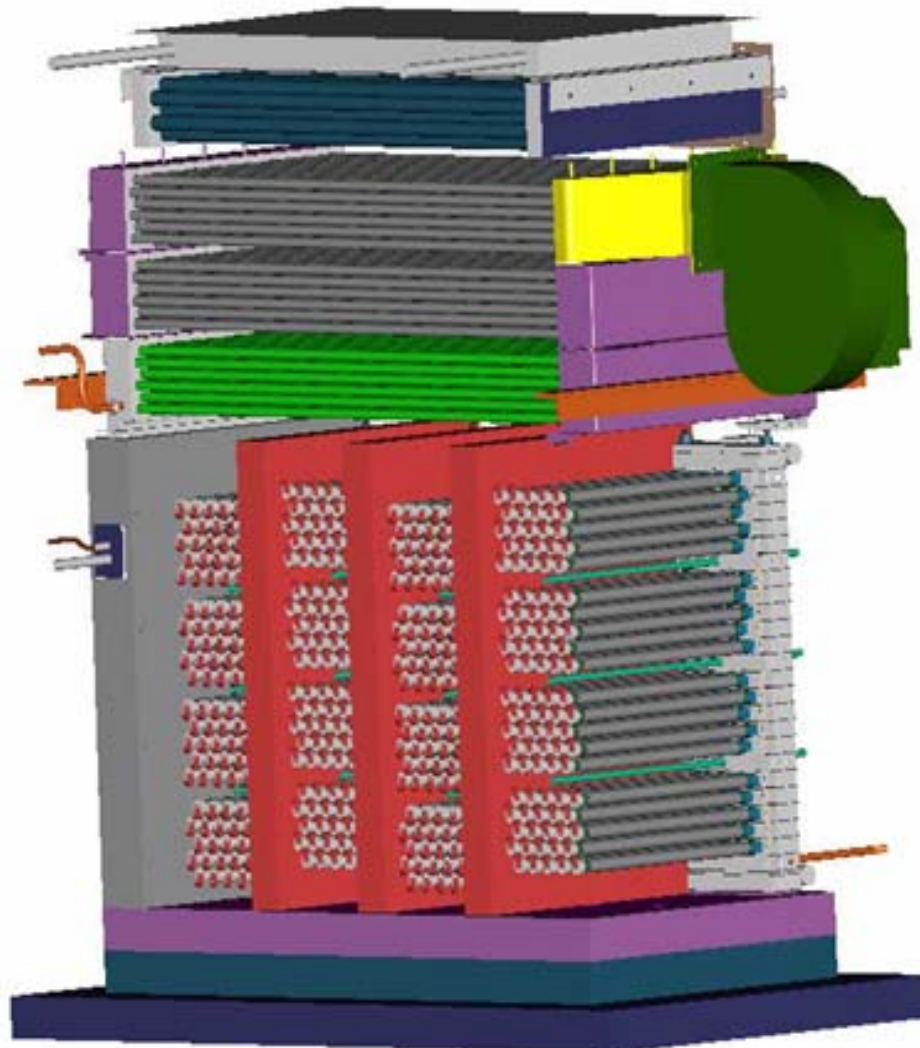
# Acumentrics Stacks During Assembly



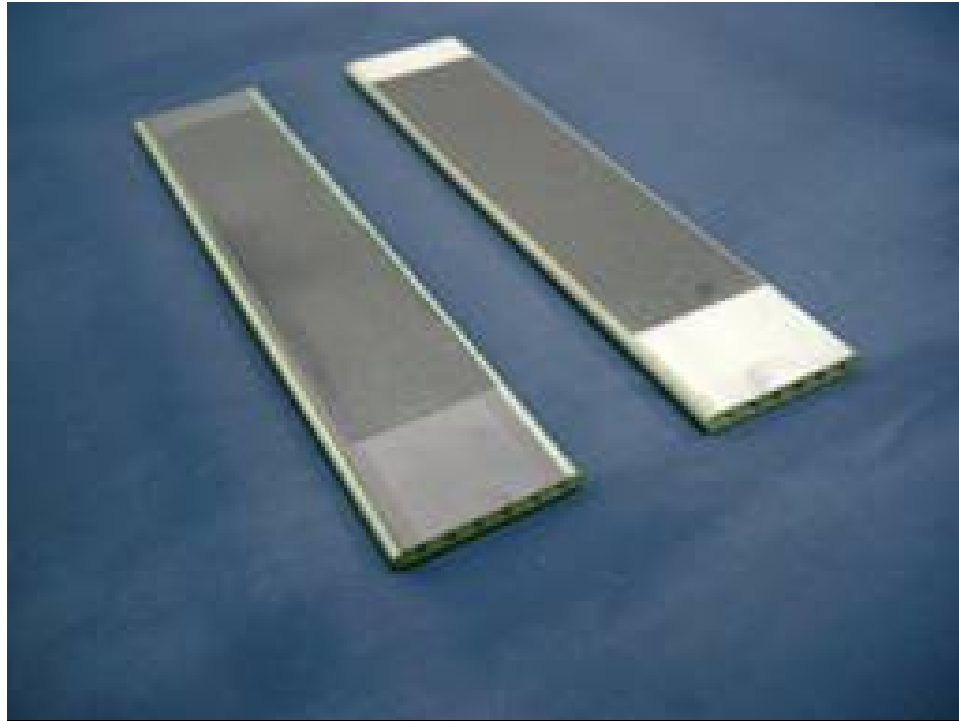
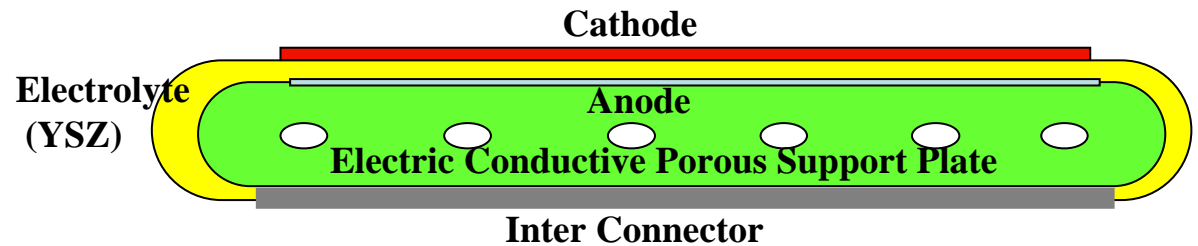
- Low pressure drop
- Minimal seal area
- Forgiving manufacturing process
- Adequate surface and flow rate for internal reforming
- Simple current collection
- Current both parallel and series



# Acumentrics Generator Design



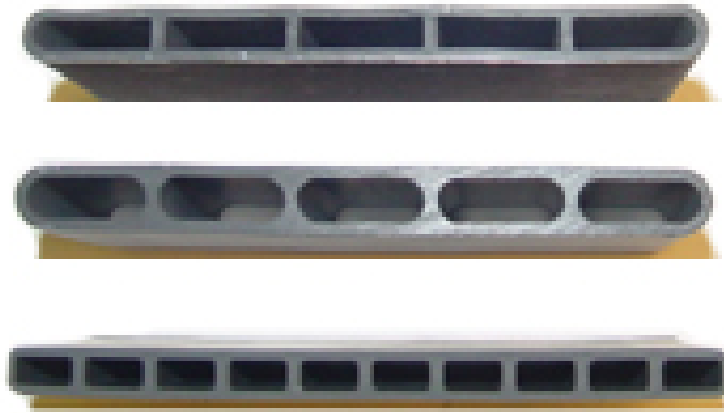
# Flattened Tubes Becoming More Popular



- Extruded base plate
- Tape-cast anode- electrolyte- cathode assembly
- Glued-on to base plate
- Electrical interconnect at end

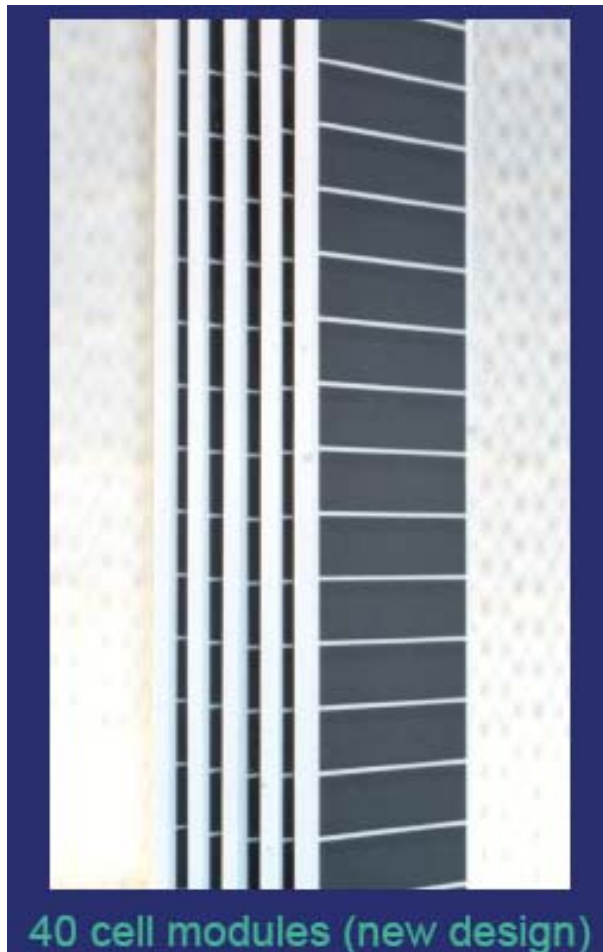
**Source: Kyocera**

# Flattened Tubes—Siemens Westinghouse



- Extruded with integral closed end cathode tube
- Electrolyte and anode coatings
- Interconnect via nickel stripe

# Flattened Tubes—Rolls Royce

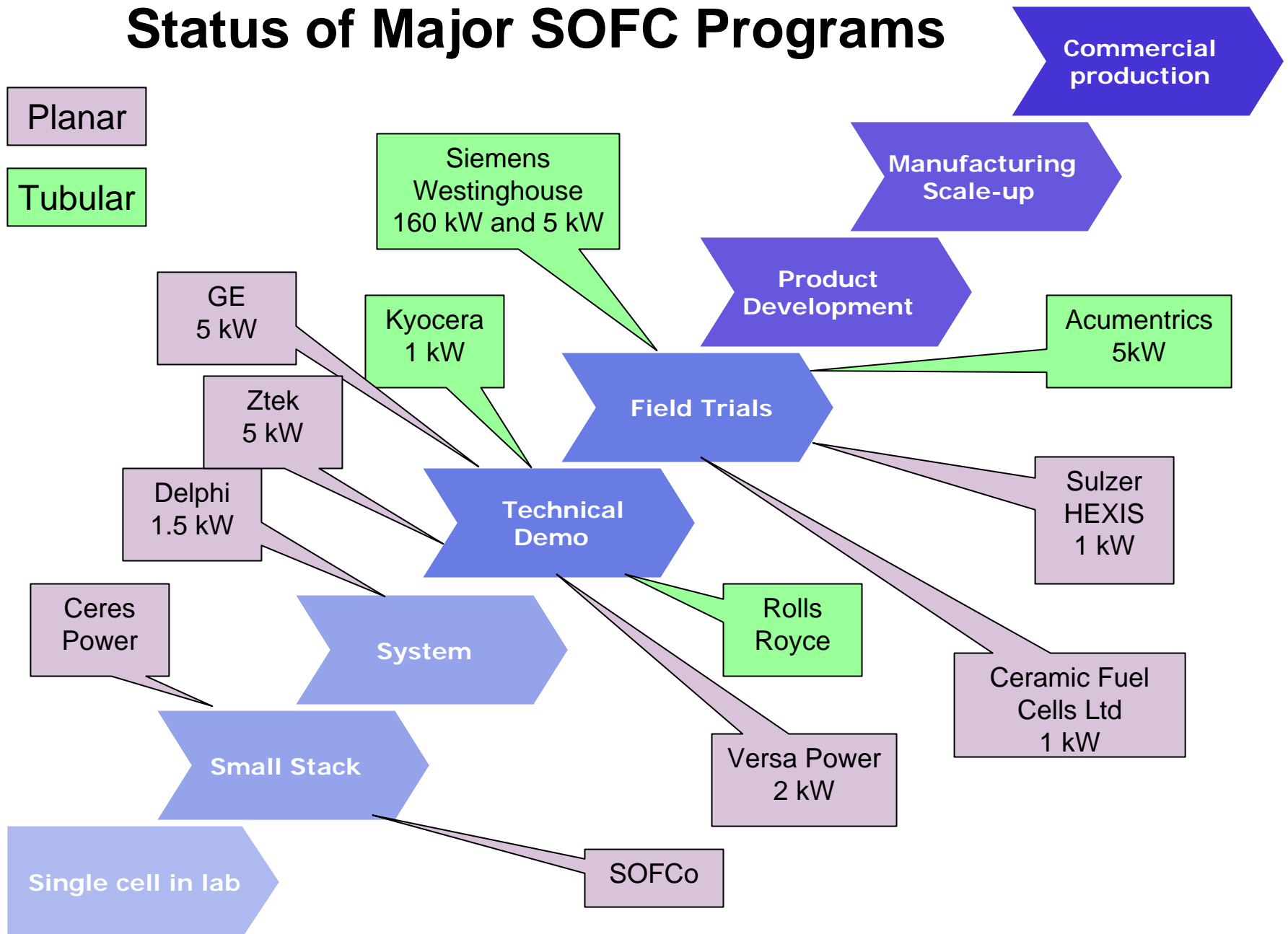


- Formed base plate
- Screen printed “window” layers
- Significant sealing area
- Interconnector at end

# Rolls Royce Stack Assemblies



# Status of Major SOFC Programs





# Opportunities

- SOFC may have best chance of being a commercially viable fuel cell technology—conventional and biofuels, quick start, durable
- Technology has advanced rapidly in last two years
- Rather than trying to pick winning technologies, try incentive contracts among multiple teams linked to achievement of milestones needed for commercial product

<b>For 4 teams, minimum 10 kW system, \$ 2 million per team</b>	<b>Time to start-up</b>	<b>Efficiency on Natural gas (AC out, HHV)</b>	<b>No. of Thermal Cycles</b>	<b>Degradation per 1000 hrs</b>	<b>Hours of operation @ 80% availability</b>
<b>To Qualify for Contract (at least 1 kW)</b>	< 2 hours	30%	15	<5%	200
<b>To Receive 50% Payment (&gt;2 kW)</b>	< 1 hour	35%	50	<3%	1000
<b>To Receive 100% Payment (10 kW)</b>	< 30 minutes	40%	100	<2%	3000
<b>To Receive 50% Bonus Payment (10 kW)</b>	< 10 minutes	45%	200	<1%	7000